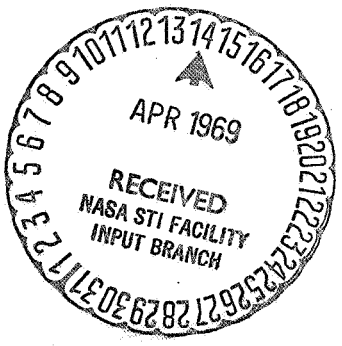
RESEARCH TRIANGLE INSTITUTE

Engineering and Environmental Sciences Division
Research Triangle Institute
Post Office Box 12194
Research Triangle Park
North Carolina 27709

BIOMEDICAL APPLICATIONS OF NASA SCIENCE AND TECHNOLOGY

Contract No. NSR-34-004-045
RTI No. EU-349



Final Report
June 15, 1967 through July 14, 1968

Prepared for

National Aeronautics and Space Administration
Technology Utilization Division
Washington, D. C. 20546

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PREFACE

This report covers the activities of the Research Triangle Institute's Biomedical Applications Team during the period from 15 June 1967 to 15 July 1968. These activities were conducted under NASA Contract No. NSR-34-004-045. The contract was performed in the Engineering and Environmental Sciences Division of the Research Triangle Institute under the technical direction of Dr. James N. Brown, Jr. Full-time members of the team and other RTI professional staff members who participated in the project are Ernest Harrison, Jr., J. B. Tommerdahl, Dr. H. G. Richter, R. L. Beadles, J. W. Murrell and Dr. D. F. Palmer.

Medical research consultants at the participating medical schools who contributed to the project are Dr. E. A. Johnson, Professor of Cardiac Pharmacology, Duke University Medical Center, Durham, North Carolina; Dr. G. S. Malindzak, Jr., Associate Professor of Physiology, Wake Forest University, Bowman Gray School of Medicine, Winston-Salem, North Carolina; and Dr. M. K. Berkut, Professor of Biochemistry, the Medical School of the University of North Carolina, Chapel Hill, North Carolina.

ABSTRACT

During the contract period, 15 June 1967 to 15 July 1968, the Research Triangle Institute's Biomedical Applications Team has interacted with 11 medical institutions which have participated in the program. During this period, the Biomedical Applications Team has worked on 149 problems submitted by researchers at the participating medical institutions. Sixty-eight of the problems were new, and the remainder were carried over from the previous contract. Fifty-five of these problems have been classified as inactive during the contract period. Twenty-eight computerized information searches and search up-dates of the aerospace literature were performed. Seven Biomedical Problem Abstracts were prepared. As a result of all searching procedures, 24 transfers of technology were accomplished, and 12 potential transfers of technology were identified. Five of these transfers were accomplished in the first year of the program, and 19 were accomplished during this contract period.

1.0 Introduction and Summary

This project has as its objective the transfer of scientific and technological results of the nation's aerospace program into the biological and medical sciences. To facilitate the transfer of scientific and technological information to clinicians and medical researchers, NASA supports three multidisciplinary Biomedical Applications Teams. The primary objectives of the applications teams are: (1) to identify problems and needs existing in the medical field which appear to be "solvable" by the application of aerospace science and technology, (2) to identify the specific technologies or concepts which may lead to solutions of these problems, and (3) to document these transfers of science and technology so as to achieve maximum utilization of the results of the program. A further objective of this program is to contribute to an increased understanding of the elements involved in the information and technology transfer process, in order to perform the transfer process more efficiently and effectively. This understanding is primarily gained as a result of the identification of difficulties which impede transfer efforts in specific practical biomedical problems and the observation of those elements which contribute to efficiency and speed in the transfer process. The teams are to apply this increased understanding of the transfer process to their field operations so as to provide a more effective interface and information channel between the life sciences and the physical sciences.

To achieve these objectives, members of the applications team discuss with researchers and clinicians at the participating medical institutions those problems that are being encountered in biological and medical research. These meetings and discussions are coordinated and, to a great extent, given direction and purpose by consultants who are staff members at the same institutions. The team seeks to understand fully both the nature of the problems and how they affect the progress of research or hinder patient treatment and care. Following these discussions, the team members specifically identify each discrete problem and translate these problems into the terminology of engineering and the physical sciences.

When appropriate, a biomedical problem abstract, a concise statement of the problem, is prepared and disseminated through the Technology Utilization

Division of NASA to the NASA research centers and other participating organizations in the space program to uncover information pertinent to a solution. At the same time, the team employs the services of NASA Regional Dissemination Centers, such as the Science and Technology Research Center located adjacent to the Research Triangle Institute, to search the computerized aerospace information bank maintained by NASA. All information obtained from information searches, biomedical problem abstracts, or the experience of applications team members and consultants is then evaluated. In addition to the team members, the medical consultants plus the researchers and clinicians who originated the problems contribute to the evaluation process. Finally, the Biomedical Applications Team encourages and, when possible, aids researchers in the application or adaption of technology identified by these activities.

Eleven medical schools and institutions are presently associated with the Research Triangle Institute's Biomedical Applications Team. They are the Duke University Medical Center, Durham, N. C.; the University of North Carolina Medical School, Chapel Hill, N. C.; the University of North Carolina Dental School and Dental Research Center, Chapel Hill, N. C.; the North Carolina State University Department of Biomathematics, Raleigh, N. C.; the Wake Forest University Bowman Gray School of Medicine, Winston-Salem, N. C.; the Veteran's Administration Hospital, Durham, N. C.; plus the Hospital for Special Surgery, and New York University of New York, N. Y.

Section 2.0 of this report contains a discussion of the 24 transfers of technology made by the Research Triangle Institute's Biomedical Applications Team. In order to be complete and to present a program summary, rather than just a progress report on this contract, all transfers made during the two-year program are summarized. To provide an indication of the criteria for defining a transfer, information which results in the following consequences is defined as a transfer:

(1) Conserves an investigator's resources by avoiding duplicatory research.

(2) Is used by an investigator to develop a proposal.

(3) Exposes technology which the investigator has reengineered for his purposes.

(4) Causes the investigator to redirect his effort to phase with other research which came to his attention as a result of the work of the Team.

(5) Causes the investigator to cancel or defer his project because it may be premature or costs that are forecasted are too high.

(6) Allows the investigator to complete his research project which might otherwise have been delayed or not finished.

(7) Results in a new biomedical product, technique, or professional conclusion.

(8) Accelerates the application of the state of the art in biomedical or medical research procedure.

In Section 3.0 the 12 potential transfers are described. Section 4.0 enumerates all the problems which have been identified and which are classified as active problems. For more detailed discussions of the active problems, the reader's attention is invited to the previous Quarterly Reports under this contract which contain detailed descriptions of activities on the individual problems.

Section 5.0 summarizes the information searching activities of the Team, which include computer searches of the NASA information banks, manual searches of the NASA information banks, problem abstracts, and a variety of miscellaneous searching procedures. In Section 6.0 the problem review activities of the Team are detailed. The problems which have been classified as inactive, along the reason for such a classification are given.

In addition to these formal activities of the Team, the Research Triangle Institute has provided to researchers at the participating institutions fabrication and testing quotations on instrumentation as such requests for quotation have been received by the Biomedical Applications Team. For example, as a result of instrumentation technology identification by the Biomedical Applications Team, the Research Triangle Institute has quoted on instrumentation priced at $44,000 for researchers at Duke University. Funds have been approved from grants held by the researchers, and part of the instrumentation has already been constructed, with the remainder in process of fabrication.

2.0 Technology Transfers

The transfers of technology which have been accomplished by the Biomedical Applications Team are discussed in the following paragraphs. For each transfer the problem and the solution are detailed, the searching method and source of solution are identified, the actual or potential benefits resulting from the transfer are discussed, and the status of the transfer is given.

DU-1

Techniques for Calculating Left Ventricular Volume from Biplane Cineradiographs

Dr. H. D. McIntosh and Dr. M. S. Spach
Duke University Medical Center

Description of Problem and Solution:

The technique presently employed in obtaining left-ventricular volume as a function of time is as follows. A radio-opaque material is injected into the blood stream, entering the left ventricle so that the left ventricle will be visible in a radiographic image. Orthogonal views of the heart are obtained using biplane cineangiocardiographic techniques. The frame rate of the systems at Duke University is 60 per second. The sequence of pictures recorded covers a time span of 3-6 seconds. Thus, several hundred images of the heart must be processed for each patient. The specific steps involved in analyzing these data are as follows. First, a physician must identify, in each frame of both orthogonal series of pictures, the inside contour of the left ventricle. Following this, a technician must determine the maximum chord of each contour and measure the width of the contour at equal intervals along the maximum chord. Then the volume is calculated from this data, assuming that the left ventricle is approximately ellipsoidal in shape throughout the cardiac cycle. This process generally requires as much as two weeks per patient, and progress of research, as a result, is relatively slow. Additionally, the technique as a diagnostic tool is severly limited.

The technological problems involved are: (1) a technique for improving image quality in the vicinity of the ventricular wall is needed to aid the physician in identifying the inside contour; (2) a means for quantifying this contour and automatically determining the maximum chord and area is needed; (3) when solutions to (1) and (2) are obtained, it is highly desirable that the entire process of data identification, acquisition, and processing be automated to the extent feasible.

The identification of the inside contour of the left ventricle can be significantly aided by the application of digital image enhancement techniques similar to those used at the Jet Propulsion Laboratory in enhancing the lunar photographs. Simple contrast enhancement can be of significant value, and by combining contrast enhancement with high frequency emphasis, the images can be improved to a greater extent. The employment of digital image processing using either flying-spot scanners or television type scanners on line with a small, general-purpose computer permits these techniques to be applied automatically.

An alternative approach to facilitate the identification of ventricular contours was suggested by Mr. L. C. Crouch, Chief of the Reconnaissance Data Acquisition Storage and Retrieval Section, Wright-Patterson Air Force Base. Mr. Crouch indicated that, since the ventricle wall occupies different positions in adjacent frames of the cineradiographs, techniques for detecting moving objects in photographic images can be applied. The two techniques suggested are (1) use of a stereoscopic viewer to look at two adjacent frames and (2) the flicker technique; i.e., to display alternately two adjacent frames from the cineradiograph at a rate of 10-20 per second using either a television monitor or optical system. These techniques are being investigated to determine if they can significantly facilitate the process of contour identification.

Use of digital image processing leads very naturally to automatic acquisition of quantitative data, such as maximum chord and area of the contour. Once these parameters are obtained for each frame of the biplane cineradiographs, volume as a function of time can be calculated and displayed either graphically on a monitor or printed out from the computer in numerical or graphic form. The final step is to automate, to the extent feasible, the

entire process of analyzing the cineradiographs. Sufficient information has been obtained at this time to state that it is entirely feasible to automate this process. By application of digital image processing (both enhancement and analysis), the time required to completely process data for one patient can be reduced from approximately two weeks to hopefully no more than one hour.

Successful Searching Method:

Computer search of NASA information banks, SIE search, and personal contact.

Source of Solution:

Information related to the solution of this problem area has come from a large number of different sources. Three computer searches of the NASA information system have been made: Analog to Digital to Topological Data, Bibliography No. 687; Pressure-Volume Measurement in the Heart, Bibliography No. 686; and Image Processing, Bibliography No. 817. A search of the files at the Scientific Information Exchange and a bibliography compiled by Mr. R. H. Selzer at the Jet Propulsion Laboratory have also been valuable. In addition to information obtained from the literature searches, a number of individuals have been extremely helpful. Dr. Robert Nathan and Mr. R. H. Selzer at JPL, as well as Mr. A. L. Fenaughty, president of Information International, Inc. in Los Angeles, have been very helpful in discussing general approaches to accomplishing the needed data acquisition and processing. Mr. L. C. Crouch, Chief of the Reconnaissance Data Acquisition Storage and Retrieval Section, Wright-Patterson Air Force Base has suggested an alternative approach to facilitate the identification of ventricular contours.

Benefits to be Derived from Transfer:

The proposed approach to obtaining ventricular volume by digital processing can greatly aid on-going investigations of left-ventricular function in both children and adults as a direct result of the ability to process and analyze greater amounts of data in less time. Ultimately, this technique can allow very rapid diagnosis of heart disease.

Current Status:

Technological feasibility of the solution to the problem has been demonstrated. A significant effort at Duke University has been expended in the preparation of a grant application to obtain the equipment and to perform the computer program development necessary to accomplish the solution to this problem. This is a completed transfer whose application is contingent upon obtaining funds sufficient to purchase the necessary equipment.

DU-6

Correction for Latency in Vidicons

Dr. E. A. Johnson, Duke University Medical Center

Description of Problem and Solution:

Dr. Johnson has for some time been using a closed circuit TV system to monitor contractions of cardiac muscle tissue. Since this tissue moves very rapidly with respect to the scan rate of conventional television systems, the image which is obtained is generally quite degraded. This results from latency or storage time in the camera tube, as well as from geometric distortion of the image caused by the significant movement of the tissue during a single frame.

The solution consists of using a stroboscopic light source which is synchronized with the 60 per second, non-interlaced framing rate of the closed circuit TV system.

Successful Searching Method:

Problem abstract.

Source of Solution:

Mr. Donald Buchele, Lewis Research Center.

Benefits to be Derived from Transfer:

This transfer has allowed Dr. Johnson to observe cardiac tissue in the contraction and relaxation processes. It is now possible to obtain quantitative data describing the length of muscle tissue as a function of time.

This information will ultimately be of value in attempts to understand the physical mechanism of muscle contraction. Additionally, this ability to observe rapidly moving tissue has allowed Dr. Johnson and other investigators at Duke to plan other physiological experiments which had not been previously feasible.

Current Status:

Completed transfer.

DU-23

Methods of Improving Resolution and General Quality of Electron Micrographs to Obtain More Information on the Structure of Cell Membranes

Dr. J. Sommer, Duke University Medical Center

Description of Problem and Solution:

Initially, discussions were directed toward the specific problem of how to improve electron micrographs of cell membranes in order to make their structure more clearly visible. Subsequently, the Applications Team has considered this problem on a broader basis. A number of problems associated with the use of the electron microscope imposes limitations upon the progress of biological research involving use of this instrument. These problems and the solutions that can be realized by the application of digital image processing are enumerated below. Physical limitations on the electron microscope include spherical aberration, astigmatism, and specimen contamination. The primary effects of these factors in an electron micrograph are: (1) reduced resolution as compared to the theoretical resolution obtainable with the electron microscope, (2) severe distortion and blurring of tissue structure, and (3) poor image contrast. Another significant problem is that staining of tissue is required to obtain a useable image of tissue structure; i.e., a material that is "electron dense", such as the heavy metals, must be added to the specimen. Frequently, the result of this staining process is severe damage to the tissue structure which is being studied. A related problem which is inherent in any imaging system used for the study of biological tissue is that enormous amounts of time

are devoted to analyzing the resulting electron micrographs. Consequently, there is a need for an automatic method for cell counting, obtaining cell diameter or length distributions and other quantitative studies, such as chromosome karotyping.

Thus, solutions to these problems in biological electron microscopy can be divided into three areas: (1) enhancement to allow visualization of latent information, (2) processing to allow an investigation of the effects of staining and to allow the use of either no stain or "weaker" stains, and (3) quantitative analyses of electron micrographs.

As a result of the information gathered on image processing as it relates to electron microscopy, a grant application has been prepared and submitted to obtain support for a program to apply these techniques in electron microscopy. (This is the same grant application referred to in the discussion of Problem DU-1. The research proposed in the application is directed toward both ventricular volume studies and processing of electron micrography.) The proposed program will initially be directed toward five specific investigative areas of physiological research. These areas are: (1) study of the contractile process in cardiac muscle, (2) studies of the development of cardiac tissue, (3) studies of junctional membrane complexes, (4) studies of structural periodicity in a number of different kinds of tissue, and (5) cytochemistry.

Successful Searching Method:

Computer search of NASA information banks, SIE search, and personal contact.

Source of Solution:

Information useable in the solution discussed above has been obtained from a number of sources including Information Search No. 819, Image Processing, a search on Image Processing from the Scientific Information Exchange, and contacts with Dr. Robert Nathan and Mr. Robert Selzer of the Jet Propulsion Laboratory.

Benefits to be Derived from Transfer:

The use of digital image processing will permit (1) obtaining more useable information from electron micrographs than can presently be

obtained, (2) an assessment of the effects of staining as compared with the information which can be obtained using contrast enhancement, and (3) quantitative analysis of electron micrographs significantly faster than can presently be done.

Current Status:

Technological feasibility of the solution to the problem has been demonstrated. Duke University has expended significant effort in the preparation of a grant application to obtain the equipment and to perform the computer program development necessary to accomplish the solution to this problem. Application of this transfer is contingent upon obtaining funds sufficient to purchase the necessary equipment.

DU-24

A Signal Conditioning and Multiplexing System for Multiple Electrode EKG Patient Monitoring

Dr. J. Boineau, Duke University Medical Center

Description of Problem and Solution:

This problem involves the simultaneous monitoring of EKG signals from multiple sites on a patient's body. Body surface potential mapping is presently being studied as a diagnostic aid in heart disease. This technique requires gathering large numbers of signals obtained from the surface of the body and subsequent processing of these signals by computers. Reliable and accurate signal conditioning circuits are required as an interface between the body electrodes and the computer input systems.

Many of the hybrid circuit designs for biomedical amplifiers at the Ames Research Center can be of value in a variety of signal conditioning systems in both medical research and patient monitoring. Indeed, some of these amplifiers would be useful in this particular application if they were available. At the present time, however, the cost of obtaining small numbers of such circuits is prohibitive. In order to be of immediate aid, the Biomedical Applications Team has arranged discussions between physicians at Duke University and instrumentation engineers at the

Research Triangle Institute to discuss specific instrumentation requirements with respect to this problem.

As a result, the Research Triangle Institute is presently designing and fabricating four, special-purpose, multichannel, signal-conditioning systems for the Duke University Medical Center using "conventional integrated circuit" techniques. Because of the fact that these four systems are to be used as research tools and are special-purpose instruments, it was felt that this was the best approach. At present, one of these units, a seven-channel, high-impedance amplifier system has been completed and is functioning at the Duke University Medical Center.

Successful Searching Method:

Personal contact and knowledge of the state-of-the-art in integrated circuits.

Source of Solution:

Research Triangle Institute and Ames Research Center.

Benefits to be Derived from Transfer:

Increased reliability and improved performance of signal conditioning circuits in medical instrumentation.

Current Status:

Portions of the signal conditioning and monitoring system have already been constructed and are in use in the Duke Medical Center. Other portions of the system are under construction.

DU-26

Cardiac Artery Constrictor

Dr. H. D. McIntosh, Duke University Medical Center

Description of Problem and Solution:

A reliable and predictable means of causing cardiac artery occlusion which, in turn, results in an infarction in experimental animals is needed. The devices would be used to study the effects of a variety of drugs and other treatments in treating coronary infarctions. The presently used device is a ring of material known as ameroid. The constrictor is

placed around the artery, and the ameroid swells as it absorbs body fluids, thus occluding the artery. It has been found that the time to occlusion of the artery following the ameroid placement on the artery varies from 12 to 60 hours. This fluctuation is highly undesirable and represents a variable factor which complicates interpretation of results. Consequently, the device must be modified, or a new approach must be taken. To be a useful experimental technique, it must be possible to cause an occlusion in 48 ± 6 hours.

Analysis of the presently used constrictor indicated that the geometry of the device appeared to be the primary factor contributing to the erratic performance. The Biomedical Applications Team suggested an alternative geometry designed to improve the performance of the device. Experiments with occlusion of flexible plastic tubing indicate that a very positive closure of the tubing is obtained with the new geometry. At present, a small number of experimental units are being fabricated, and physicians at Duke University are planning to evaluate their operation.

Successful Searching Method:

Experience of Biomedical Applications Team Members.

Source of Solution:

Biomedical Applications Team.

Benefits to be Derived from Transfer:

A successful device will permit collection of data with greater precision.

Current Status:

Experimental units are being tested at present time.

DU-28

Fluid Dynamics of Sucrose Gap Chambers

Dr. E. A. Johnson, Duke University Medical Center

Description of Problem and Solution:

Sucrose gap chambers are used frequently in physiological research when it is necessary to electrically isolate small regions (on the order

of .010 inch) of single cells or fibers of nerve or muscle tissue. This isolation is achieved in sucrose gaps by flowing alternate streams of sucrose (an insulator) and Krebs solution (a conductor) over these cells.

Presently available sucrose gap chambers can be used with relatively large nerve cells, such as the giant squid axon, but because of fabrication difficulties they have not in the past been built small enough for cardiac muscle cells and smaller nerve cells on the order of 20-30 microns in diameter. Reduction in size of the sucrose gap chamber for these smaller cells requires completely new approaches to fabrication which in turn necessitate that the basic configuration of the chamber itself be changed. This change in chamber configuration means that the operation of smaller chambers cannot be predicted by simple extrapolation from existing designs. Thus, the design of a new smaller chamber required that new empirical or theoretical information on fluid dynamics be obtained. Relevant documents on fluid dynamics and design of fluid amplifiers and logic circuits has been furnished to the researcher. These documents were reports on NASA-supported programs to develop fluid amplifiers and logic circuits. Information in these reports has allowed Dr. Johnson to design a new chamber with reasonable certainty of successful operation for studying the characteristic of single cardiac muscle fibers.

Successful Searching Method:

Search of the NASA literature.

Source of Solution:

A manual search at STRC produced six NASA contractor reports related to fluid dynamics in small passageways and chambers.

Benefits to be Derived from Transfer:

The design of smaller gap chambers has been aided by this information. It will be possible to study more precisely the electrical properties of cardiac muscle cells.

Current Status:

Transfer completed.

DU-29

Methods of Fabricating Small Sucrose Gap Chambers

Dr. E. A. Johnson, Duke University Medical Center

Description of Problem and Solution:

Sucrose gap chambers in the past have been made from lucite and were fabricated by drilling all holes and fluid passages using a milling machine. The process is generally expensive, and one is limited in just how small the chamber can be made. The applications team suggested that, if the sucrose gap chamber could be laid out in a planar configuration, then it could be fabricated using autolithographic and etching techniques similar to those employed in obtaining oxide diffusion masks on silicon in the fabrication of silicon integrated circuits.

Through the Science and Technology Research Center, two different processes were identified which could be appropriate. Bowles Engineering, Incorporated has developed a technique for selectively etching channels into plastics for fabricating fluid amplifiers. This process, however, requires the sue of plastics which are somewhat soluble in water and, therefore, could not be used in fabricating sucrose gap chambers. Another technique developed by Corning Glass Corporation does appear applicable. This particular process involves selectively exposing portions of a glass plate to ultraviolet radiation. The exposed regions, following development by heating, etch at a rate of from 25 to 30 times faster than the etching rate in the unexposed portion of the plate. Thus, it is possible to form intricate patterns or channels to the desired depth in glass. The chamber itself can be formed by etching appropriate patterns into the surfaces of two plates and then pressing these plates together to form the desired fluid system.

Successful Searching Method:

Information obtained from the Science and Technology Research Center.

Source of Solution:

Corning Glass Corporation.

Benefits to be Derived from Transfer:

This procedure should permit the fabrication of better sucrose gap chambers at a lower cost than is presently possible.

Current Status:

It is expected that experimental sucrose gap chambers will be fabricated and tested in the near future.

HSS-1

Method of Measuring and Telemetering Force Applied to Broken Bone Joints by Implanted Braces

Dr. H. Amstutz, Hospital for Special Surgery

Description of Problem and Solution:

Researchers at the Hospital for Special Surgery require a method of measuring and telemetering the force applied to broken bone joints by compression fixation devices. Compression plates approximately 8 centimeters long and one centimeter wide would be attached to fractures that had been induced in one of the long bones of a dog or perhaps a mini-pig. It is desired to monitor continuously the pressure or strain existing internally in the plate. The experiment would follow the acute fracture to its healing point, which in the dog would be approximately six weeks.

The Ames telemetry and pressure measuring system is applicable to this problem, and full information on the Ames unit has been supplied. Efforts at the Hospital for Special Surgery are being directed toward fabricating and purchasing experimental telemetry units.

Successful Searching Method:

Personal contact with researchers at the Ames Research Center.

Source of Solution:

Ames Research Center.

Benefits to be Derived from Transfer:

Solution of this problem will permit researchers to measure, as a function of time, the stress on fractures as applied by compression

fixation devices. The time period over which these devices apply pressure on the healing joint is not known. It is known that pressure on the joint increases the healing rate, and correlation of pressure on the joint with healing rate would be very desirable. This knowledge would permit evaluation of whether present compression fixation devices are effective during the entire healing period. If they are not effective over the entire healing period, it may be desirable to redesign these devices to permit application of pressure over the entire healing period with the desired goal being a decreased healing time.

Current Status:

Information necessary to construct the Ames telemetry system has been supplied.

NCSU-2

Information on Environmental Capsules for Opossums

Dr. J. Sedensky, North Carolina State University

Description of Problem and Solution:

A researcher at North Carolina State University is interested in beginning a new project to study sleep mechanisms at very early stages in animal development. Consideration of possible animals to be used as experimental subjects for this study led to the identification of the embryo of the opossum as a possible subject. It was desired to maintain the embryo of the opossum in an environmental chamber external from the mother opossum. This perhaps could be accomplished with greater ease for the opossum than most other animals. The advantage of using an embryo is that, during the embryo stage, development is extremely rapid so that the time scale for observations is greatly compressed. The researcher required information on methods by which the opossum embryos could be maintained for a prolonged period of time, i.e., until embryotic development is complete.

The Biomedical Applications Team was asked to determine if information on environmental facilities suitable for such studies had been developed

in the NASA aerospace program, so that an evaluation of the opossum as a suitable test animal could be made. A selective search of the aerospace literature revealed a report for a marsupial biomule evaluation study. In this study, the opossum embryo was considered as a subject for satellite experiments to obtain information about the developmental effects of weightlessness and radiation in a telescoped biological time period. In this study, a complete life support system and environmental system for the opossum embryo was developed and evaluated.

Successful Searching Method:

Manual search of the NASA information system.

Source of Solution:

A report originating from Aerospace Medical Division, Air Force Systems Command, Brooks Air Force Base, Texas.

Benefits to be Derived from Transfer:

Information furnished by the Biomedical Applications Team on environmental and support housing for opossum embryos has been used by the researcher to evaluate the suitability of the opossum as a test animal for this proposed project.

Current Status:

The information has been used to support the choice of a test animal in presentations seeking research funds for the project.

UNC-2

Bone Growth and Resorption Mechanisms

Drs. D. L. Allen and W. T. McFall, Dental Research Center, University of North Carolina

Description of Problem and Solution:

Drs. Allen and McFall are interested in methods of stimulating bone growth electrically as a means for rebuilding tooth-supporting bone tissue which has been resorbed. The applications team has designed a simple mechanism which allows direct current stimulation of bone tissue on rat skulls without significantly restricting the normal activity of the rats.

The Research Triangle Institute has supplied 12 of these mechanisms to the Dental Research Center to allow initial experimental work to begin. Experiments have been undertaken to gain some understanding of growth and resorption processes in bone and how these processes are affected or controlled by electrical charge distributions in tissue.

It has been suggested by Bassett[1] that both growth and resorption of bone tissue are controlled by electrical phenomena. Also, it has been demonstrated that bone tissue is piezoelectric and that this piezoelectric characteristic of bone tissue may serve as the primary feedback mechanism involved in the process of strengthening bone tissue which is regularly subjected to relatively large amounts of mechanical stress. It is possible that the loss of calcium in skeletal bone in astronauts results from the absence of mechanical stress on the skeleton in this weightless environment. It is hoped that some method for applying the results of space flights can be applied to increasing the understanding of these phenomena in general.

Successful Searching Method:

Experience of Biomedical Applications Team members.

Source of Solution:

Biomedical Applications Team.

Benefits to be Derived from Transfer:

This research program is directed to investigation of the fundamental processes involved in stimulation of bone growth. The goal of this research is to apply such information to rebuilding tooth-suppporting bone tissue that has been resorbed.

Current Status:

The experimental portions of this program are carried out during the summer sessions of the school year. The Biomedical Applications Team is continuing to participate, on a consultative basis, in the research program to be undertaken during the summer session this year.

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[1] C. A. L. Bassett, "Electrical Effects in Bone," Scientific American, Vol. 213, Oct. 1965, pp. 18-25.

UNC-9

Analysis of Electrophoretic Radioactivity Scan Data

Dr. J. J. Van Wyk, University of North Carolina Medical School

Description of Problem and Solution:

Dr. Van Wyk at the UNC School of Medicine was faced with a problem of analyzing several hundred radioactive electrophoresis scan samples for each patient examined. These samples were counted on a radioactivity counter, and the area under a radioactivity curve analyzed by planimetric methods. Analysis of approximately 200 samples for each patient took on the order of 24 hours of actual work. This resulted in a time lag of several weeks between the examination period and the time when the data was obtained from the recorded information. The solution was a new method of counting the samples.

Successful Searching Method:

Familiarity of a Biomedical Applications Team member with radioisotope techniques and instrumentation.

Source of Solution:

Biomedical Applications Team member.

Benefits to be Derived from Transfer:

With the new procedure which has been adopted routinely for all samples in the future, the time for analysis has been reduced to one or two hours of actual operator time as contrasted with the approximately 24 hours of work required previously.

Current Status:

Completed transfer.

UNC-12

Low Temperature Lubricant for Microtomes

Dr. W. J. Waddell, Dental Research Center
University of North Carolina

Description of Problem and Solution:

Dr. Waddell had experienced difficulties in preparing thin tissue sections with a microtome operated at sub-zero temperatures. The difficulty was

attributed to an inadequate lubricant in the microtome mechanism. At sub-zero temperatures, the lubricant which was being used did not adequately lubricate the carriage mechanism for the knife blade. This resulted in binding and excess friction which prevented the preparation of uniform thin sections. An advanced solid lubricant was identified which provides adequate lubricating properties at these low temperatures.

Successful Searching Method:

Manual search of NASA literature.

Source of Solution:

The solution to this problem was found in NASA document SP-5095, "Solid Lubricants." A special lubricant cited in this document was employed and found to be very appropriate for this application.

Benefits to be Derived from Transfer:

The use of this lubricant on the microtome has permitted the researcher to produce much more useable sample sections with the microtome at sub-zero temperatures.

Current Status:

Completed transfer.

UNC-13

Methods of Reinforcing Thermoplastic Braces and Casts

Miss Florence Bearden, University of North Carolina School of Medicine

Description of Problem and Solution:

Elderly arthritic patients frequently use hand braces to keep their hands in particular positions for therapeutic purposes. These braces are easily removed for the advantage of the patient. Frequently, however, they are placed in hot water or in the sunlight. Since the materials, which heretofore were used for fabrication, are sensitive to heat, the braces would deform. The solution was to employ fiberglass as a reinforcing material in the cast and braces. This material does not deform at the low temperatures of the plastics which were previously employed.

Successful Searching Method:

Suggestion from one of the members of the Biomedical Applications Team.

Source of Solution:

Biomedical Applications Team.

Benefits to be Derived from Transfer:

Preliminary experiments have been made and have shown that this approach will solve the problem. Since the braces are made in the hospital to fit the individual patient, it is very easy to add the fiberglass reinforcement at the time of fabrication. This leads to low cost braces and orthotic appliances which will withstand the normal temperatures with which they might come into contact under normal use.

Current Status:

Completed transfer.

UNCD-11

An Improved Bacteria Sampling Technique

Dr. J. J. Crawford, Dental Research Center,
University of North Carolina

Description of Problem and Solution:

Dr. Crawford is engaged in a research program to identify and quantify the bacteria found in the upper respiratory tract and the oral cavity of a number of children with and without complete development of the nasal and palatal tissues. The research program is being carried out by sampling a number of children on a regular basis. Since these children are regularly available, the accumulation of valuable information on the development and growth of bacteria in the respiratory and nasal passages in various conditions of nasal and palatal development is permitted. Samples are obtained from three areas on each person--the nose, the throat, and the midnasal pharynx.

The sampling technique now being used is uncomfortable and even painful to the children being sampled. The researcher is seeking a means of sampling bacteria in the nasal pharyngeal passage which is

simpler and less unpleasant to patients than the currently used method. The presently used technique is as follows: a speculum is used to permit entry into the nasal pharynx through the nose. A small wire, usually aluminum, which has a ball of alginate wool on the end is passed through the speculum and into the nasal cavity. The ball of wool is made to come into contact with the tissue floor in the nasopharyngeal passage, thus collecting the bacteria. The swab is then removed and processed to obtain the bacteria cultures.

A computer search of the NASA literature on assay of microorganisms was conducted which yielded 117 hits. Of these, 33 were of direct interest to the researcher. The search revealed that several areas of common interest exist between infectious oral disease research and NASA research. They are:

(1) Asepsis and the technology for detecting and monitoring microbial cross contamination as applied to clinical dentistry.

(2) Methodology of disinfection and sterilization and aseptic control of airborne microorganisms.

(3) Sampling of oral and respiratory passages for detection of microorganisms.

(4) Bacterial identifications related to occurrence and changes of pathogenic and indigenous species of the oral and respiratory passages.

(5) Effects of changes in environment, developmental physiology, and stress on oral and upper respiratory flora.

Of particular interest and assistance were several articles on sampling culture procedures and flora changes of personnel enclosed in controlled chamber environments for long periods of time.

A basic solution to the researcher's problem of finding an improved bacterial sampling technique has not been identified. However, information resulting from the search which established and identified several common areas of interest between infectious oral disease research and NASA research has permitted a transfer of information. NASA research documented in the articles furnished the researcher has been of direct interest, and information contained therein has been cited as background information

in a request for grant funds in the field of "Bacteria Classification in the Upper Respiratory Tract".

Successful Searching Method:

Computer search of NASA information banks.

Source of Solution:

NASA reports in the field of assay of microorganisms.

Benefits to be Derived from Transfer:

Information supplied by the Biomedical Applications Team has been used in support of a grant application for research funds in this field of research.

Current Status:

Information is still being sought which may lead to an improved bacteria sampling technique.

UNCD-13

Economical Dry Heat Sterilization Apparatus

Dr. J. J. Crawford, Dental Research Center, University of North Carolina

Description of Problem and Solution:

Dr. Crawford has been interested in means to sterilize dental instruments that are economical and easy to implement. Specifically, the evaluation and establishment of sterilization procedures in dental clinics was of primary concern. Also, the efficiency of steam versus dry heat sterilization of dental instruments in the oral micro-biology laboratory was of interest. Information on various sterilization and heating techniques obtained from a variety of sources was discussed and evaluated by the researcher and the Biomedical Applications Team. To supplement this information, an extensive list of commercial manufacturers of hot air ovens was provided. Data was obtained by Dr. Crawford on the most appropriate commercially available hot air ovens. Comparisons were made among the various equipments and techniques available. It was concluded that two specific commercial models of hot air ovens provided adequate efficiency, greater capacity, and more convenience at a lower cost.

These units presented significant advantages over steam for sterilizing delicate, non-stainless dental instruments. As a result of these activities, specific recommendations have been made by the researcher to the Dental School on sterilization equipment for use in dental laboratories and clinics of the school. These dry heat ovens are already being used in a number of clinics, and their utilization is planned for others.

Successful Searching Method:

Manual searching of NASA literature plus experience of the researcher and members of the Biomedical Applications Team.

Source of Solution:

Choice of sterilization method resulted from a number of sources including NASA literature, commercial literature, and the experience of the researcher and members of the Biomedical Applications Team. Choice of the specific types of equipment resulted from comparison of literature on commercial units.

Benefits to be Derived from Transfer:

Efficient, dry-heat ovens are being used in a number of clinics at the Dental School. These units present significant advantages over steam for sterilizing delicate, non-stainless dental instruments. They have greater capacity, are more convenient to use, cost less, and are of adequate efficiency.

Current Status:

Completed transfer.

UNCD-14

Design of Clean Rooms, Especially Laminar Flow Clean Rooms

Dr. J. J. Crawford, Dental Research Center, University of North Carolina

Description of Problem and Solution:

The Dental School of the University of North Carolina is now in a building and expansion program to increase their facilities. Information was needed on the design of clean rooms. In particular, laminar flow

clean rooms were considered to be most appropriate. To aid in initial planning and to provide an information background upon which to base clean room design decisions, information on advanced clean room design was needed. A selective search of the NASA literature revealed a number of documents on clean room design. Several were extremely pertinent and very complete in their specification of design criteria. These documents were furnished to the researcher and will provide the basis for the evolution of the design of clean room facilities in the new Dental School building.

Successful Searching Method:

Selective computer search of the NASA literature.

Source of Solution:

A number of the documents resulting from the literature search were extremely pertinent and complete in their specification of design criteria for laminar flow clean rooms.

Benefits to be Derived from Transfer:

During the planning for construction of the new Dental School building at the University of North Carolina, the most up-to-date NASA techniques in laminar flow clean room design have been made available to planners involved in the design of the physical plant. Much of the information has been determined to be useful, not only from an informative standpoint, but also from a practical viewpoint with regard to planning of the physical facilities of the new Dental School building.

Current Status:

Completed transfer.

WF-6

Seven-channel, Portable, Battery-operated Tape Recorder

Dr. J. F. Toole, Bowman Gray School of Medicine,
Wake Forest University

Description of Problem and Solution:

Dr. Toole of the Bowman-Gray School of Medicine has expressed the need for a small, lightweight, seven-channel, biomedical tape recorder that can

be used for recording physiological parameters of subjects in their normal environment. Basic requirements for the recorder are simplicity of operation and the capability for recording for at least eight hours.

The solution to this problem has been identified as a portable, battery-operated tape recorder commercially available from Lockheed Electronics Company. This unit appears to have all of the capability required by the researcher. The recorder has been evaluated by the researcher, and he reports that the unit is very suitable for use in his project.

Successful Searching Method:

A seemingly acceptable solution to the problem was found in a NASA-developed biomedical tape recorder at Edwards Air Force Base. Requests were made over an extended time to obtain demonstration units for the researcher. They were not available because of a program requiring full-time utilization of all available units. Next, the developer of the recorder for NASA was contacted to see if acceptable units could be manufactured to commercial specifications. The cost of such re-engineering was prohibitive. Finally, we initiated a thorough search of the commercial literature to locate any commercial magnetic tape recording devices which might fit this particular application. The Lockheed Electronics Company tape recorder was identified as being applicable to this problem.

Source of Soluction:

In-depth searching of the commercial literature.

Benefits to be Derived from Transfer:

This recorder will permit the accumulation of data on physiological parameters of interest over extended periods of time while the subject is performing normal activities. The gathering of data in hospitals, clinics, and doctor's offices does not represent the true condition of subjects many times because the symptoms of interest only occur during the normal working environment and cannot be produced at the physician's office. In addition, this type of data has generally been unavailable to researchers because no satisfactory means has been found to gather the data.

Current Status:

Completed transfer of information.

WF-7

Method of Correcting for Spherical Aberration in Ultrasonic Holograms

Dr. F. L. Thurstone, Bowman Gray School of Medicine,
Wake Forest University

Description of Problem and Solution:

A number of investigators are presently studying a unique technique for displaying the structure of internal organs of the human body. This technique involves the generation of an optical hologram from the information contained in ultrasonic energy reflected from internal physiological structures. Since the ultrasonic energy has a wavelength of approximately 0.3 mm and the optical images are reconstructed using light having a wavelength approximately three orders of magnitude smaller, the reconstructed image contains significant spherical aberration. This aberration appears as a general degradation of the image. The solution which has been identified is the use of digital image processing to remove spherical aberration from the holograms.

Successful Searching Method:

Problem abstract, information searches, and personal contact.

Source of Solution:

Problem abstract responses and reports obtained from information searches, as well as information and reports obtained from the Jet Propulsion Laboratory.

Benefits to be Derived from Transfer:

The development of ultrasonic holographic techniques has been advanced by this transfer. Ultrasonic holography itself is being studied for the following three reasons. First, ultrasonic energy does not appear to be dangerous to the body as are X-rays. Second, ultrasonic energy is reflected from interfaces between different types of soft tissue and therefore allows visualization of structures which cannot be "seen" on radiographic images. Third, the image obtained with ultrasonic holography is three-dimensional.

Current Status:

Completed transfer.

WF-10

Theoretical Treatments of Holography which Discuss Aberrations and Distortions

Dr. F. L. Thurstone, Bowman Gray School of Medicine,
Wake Forest University

Description of Problem and Solution:

Ultrasonic holography may, in the future, give the physician and researcher the ability to visualize, in three-dimensions, the soft tissue structures within the body. The technique presently is in the research stage. This research can be aided significantly by having available all information on distortions and aberrations which can occur in holography. A large amount of information has been supplied to the researcher which describes mathematically the most significant distortions in holography.

Successful Searching Method:

Computer search.

Source of Solution:

Open literature.

Benefits to be Derived from Transfer:

The researcher's work in ultrasonic holography has been advanced. It is difficult at present to evaluate the benefit which can be realized in the medical field.

Current Status:

Completed transfer.

WF-13

Radiation Detector for In-Vivo Measurement of Absorbed Dose

Dr. D. D. Blake and Mr. F. C. Watts, Bowman Gray School of Medicine,
Wake Forest University

Description of Problem and Solution:

The need exists at Bowman Gray School of Medicine for a radiation sensor in the configuration of a small probe which can be inserted directly into living tissue or into cavities of the human body. The techniques

presently used for measuring dose in radiation therapy do not, in fact, give a measrue of tissue dose. Rather, what is determined is exposure to radiation. There is a need for a technique of measuring radiation dosage inside body cavities and tissue. The solution to this problem is a solid-state radiation detector manufactured by Solid State Radiation, Inc.

Successful Searching Method:

NASA Tech Brief 66-10252 describing a biomedical radiation probe led the Biomedical Applications Team to contact Mr. John T. Wheeler at the Manned Spacecraft Center in Houston. Mr. Wheeler indicated that Solid State Radiation, Inc. of Palo Alto, California, has done considerable development of probes and sensors for NASA and the Atomic Energy Commission. The president of Solid State Radiation, Inc., Dr. Henry Katzenstein, was contacted, and a meeting with Dr. Katzenstein and members of the medical staff of the Bowman Gray School of Medicine was held at the Research Triangle Institute. Solid State Radiation, Inc. supplies these probes to selected medical researchers under a program sponsored by the Atomic Energy Commission.

Contact was made with Dr. Hodge Wasson, of the Atomic Energy Commission to explore means whereby one of these probes could be made available to the researchers at Bowman Gray. Following these contacts, arrangements were made to obtain a sample probe for the Bowman Gray School of Medicine. Figure 1 illustrates the probe which was obtained from Solid State Radiation, Inc.

Source of Solution:

A commercial firm, Solid State Radiation, Inc., presently under contract to the Atomic Energy Commission. The initial lead to the existence of the probes was obtained from a NASA Tech Brief.

Benefits to be Derived from Transfer:

This transfer of technology will permit the accumulation of data on actual dosage to specific portions of the human body which cannot be obtained by other means.

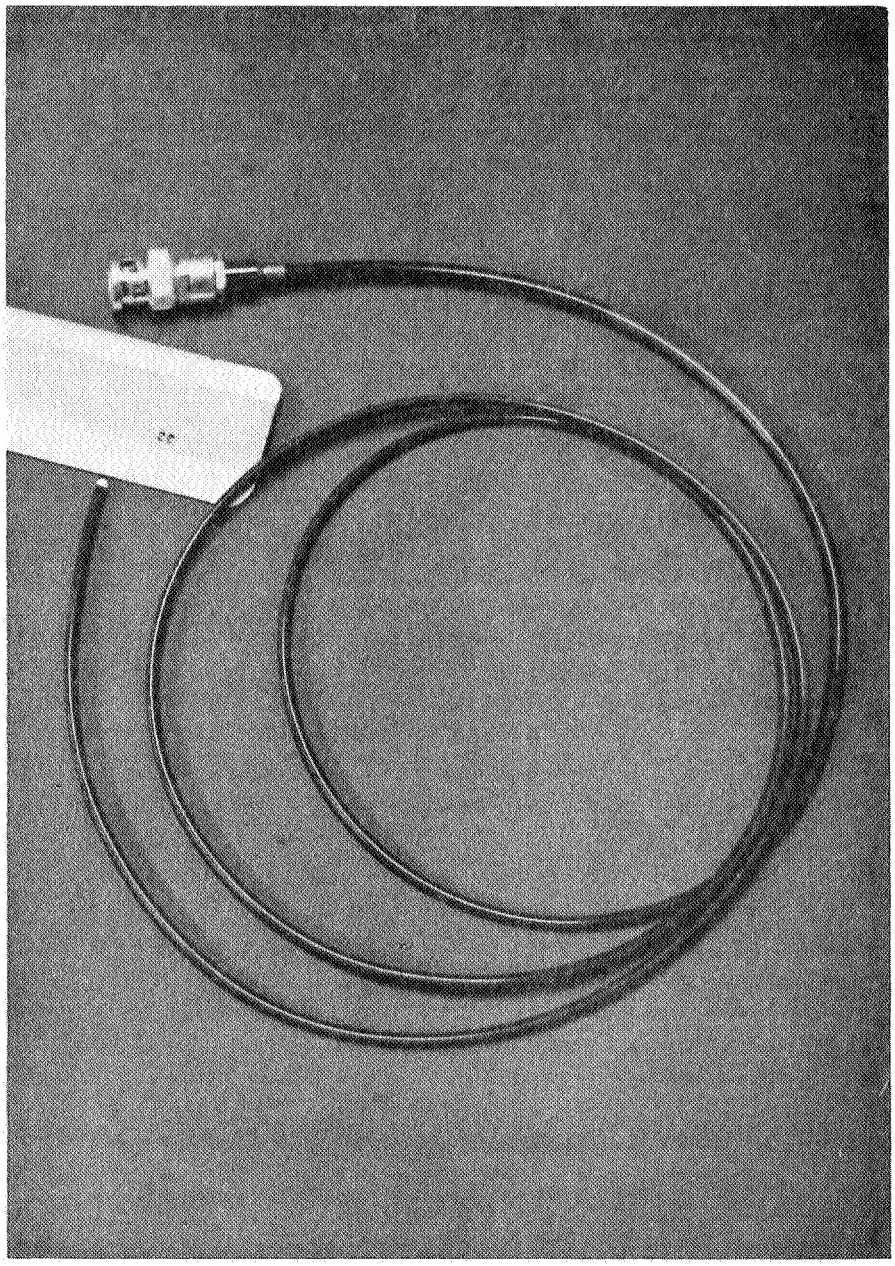

Figure 1 - Semiconductor Radiation Probe.

Current Status:

Completed transfer.

WF-30

An Improved Blood Vessel Constrictor

Dr. G. L. Malindzak, Jr., Bowman Gray School of Medicine,
Wake Forest University

Description of Problem and Solution:

An improved blood vessel constrictor applicable to open surgery is needed. The constrictor must be capable of controlled constriction of blood vessels and instant release.

In cardiac and vascular studies at the Bowman Gray School of Medicine, Wake Forest University, investigators frequently need some device that can be placed around a blood vessel during open surgery to cause a controlled stricture of the vessel. Currently used devices possess several disadvantages. First, these devices are relatively difficult to release rapidly. It is important that the constriction on the blood vessel be removed rapidly because experiments frequently require that the blood flow be reduced to the point that the test animal will die unless immediate release of the constrictor can be accomplished. These test animals are carefully controlled and instrumented, and their histories are well-known. Loss of such an animal represents a significant loss of time and money. Consequently, instant release of the constriction is of great importance. In addition, most configurations currently available are bulky and difficult to operate.

A commercially available blood constrictor operating on a pneumatic or hydraulic principle has been identified as being potentially useful in the solution of this problem. In addition to this potential transfer of technology, information and consultation furnished by the Biomedical Applications Team has been used by the researcher as supporting information in a grant application for research funds, resulting in a definite information transfer.

Successful Searching Method:

Active consultation with the researcher has resulted in the information transfer. The potential transfer of technology was received as a result of a problem abstract.

Source of Solution:

The transfer of information was the result of joint consultation between members of the Biomedical Applications Team and the researcher. The potential transfer of technology was suggested by a member of the Southwest Research Institute's Biomedical Applications Team.

Benefits to be Derived from Transfer:

An improved occluder will permit saving the life of valuable experimental animals.

Current Status:

The information supplied by the Biomedical Applications Team has been used by the researcher as supporting information in a grant request. The commercially available constrictor has been ordered by the researcher. Applicability of the occluder to this problem will be evaluated when the unit is received.

WF-39

Information on the Physiological Effects Arising from the Use of Short-Lived Radioisotopes in Treatment and Autoradiography

Dr. D. J. Pizzarello, Bowman Gray School of Medicine,
Waske Forest University

Description of Problem and Solution:

In recent years, short-lived isotopes have been developed and used in treatment. Generally, these isotopes have been administered on the basis of not exceeding a specified total dose. However, because of their extremely short half-life, the dose rate is extremely high. It is well known that the

response of living cells to radiation varies with the dose rate. The severity of tissue damage as a result of extremely high dose rate is attributed to the fact that radiation damage occurs repetitively before the cell can recuperate from a previous hit from ionizing radiation. There are felt to be other perhaps more subtle reasons for the differential response of living cells to varying dose rates. The researcher desired to determine whether such information resided in the NASA system. This information would be valuable not only from a clinical standpoint, but for two reasons. First, Dr. Pizzarello is engaged in the teaching program of the university and wishes to incorporate such information into a course on autoradiography being given to resident physicians. Second, because of a personal interest in this particular area of investigation and the desire to pursue research in this area, he wished to obtain information in the NASA system which would be useful as background and supporting information for a research grant application in this field. A retrospective search, ("Short Half-Life Radiation Medicine," Search No. 1212) was made. This search yielded 54 citations, and significant information relating to this problem was found as a result of this search. The researcher is preparing a grant application in this field of activity. Information furnished by the Biomedical Applications Team is being used as supporting information in this request.

Successful Searching Method:

Computer information searching of the NASA information banks.

Source of Solution:

Information Search No. 1212,"Short Half-Life Radiation Medicine," performed by STRC.

Benefits to be Derived from Transfer:

Information furnished by the Biomedical Applications Team is being used as supporting information in the generation of a grant request for research funds.

Current Status:

Grant request is in process of preparation.

WF-45

Sensitivity of Animal Cells to Radiation as a Function of Amount of Oxygen Present in Tissue and as a Function of Radiation Dose Rate

Dr. D. J. Pizzarello, Bowman Gray School of Medicine,
Wake Forest University

Description of Problem and Solution:

This problem centers about the fact that the presence of oxygen in tissue tends to worsen the effect of radiation on the tissue. In addition, the effect of oxygen depends on dose rate; that is, the effect of densely ionizing radiation on tissue is not affected by the presence of oxygen nearly as much as when sparsely ionizing radiation is used. These two effects and their interrelationships are considered to be important. Yet, the mechanisms involved in these effects have not been clearly identified. Dr. Pizzarello is interested in information residing in the NASA system which is the result of experimentation in this area and which affords an explanation of either of these two effects or their interrelationships.

A search, "Short Half-Life Radiation Medicine," of the NASA information banks was made. Information directly related to this problem was obtained from the search. This information which was supplied by the Biomedical Applications Team is being used by the researcher as supporting and background information in the preparation of a grant request for research funds.

Successful Searching Method:

Computer information searching of NASA information banks.

Source of Solution:

Information Search No. 1212, "Short Half-Life Radiation Medicine," performed by the Science and Technology Research Center.

Benefits to be Derived from Transfer:

Information furnished by the Biomedical Applications Team is being used as supporting information in the preparation of an application for research funds.

Current Status:

Grant request is in process of preparation.

WF-50

Application of Time-Series Analysis to Computer Processing of Biomedical Data

Dr. G. T. Malindzak, Jr., Bowman Gray School of Medicine,
Wake Forest University

Description of Problem and Solution:

Dr. Malindzak of the Department of Physiology of the Bowman Gray School of Medicine is actively engaged in computer analysis of physiological data. He is interested in the application of time-series analysis to certain types of physiologic data. A request for basic information in this field was made to the Biomedical Applications Team. The Biomedical Applications Team arranged for an RTI specialist in signal-analysis techniques to confer with Dr. Malindzak and discuss the application of such techniques to this type of data. The information transfer resulting from these interactions was judged by the researcher to be extremely relevant. This information has been used by Dr. Malindzak as supporting data in the preparation of four grant requests for research funds.

Successful Searching Method:

Identification of a professional member of the Research Triangle Institute's research staff with expertise in the specific field pertinent to the problem.

Source of Solution:

Professional staff of Research Triangle Institute.

Benefits to be Derived from Transfer:

Information furnished as a result of the Biomedical Applications Team activity has been used as supporting information in the preparation of four grant applications for research funds.

Current Status:

Grant requests have been submitted.

3.0 Potential Transfers

When a solution to the problem has been identified that appears to fulfill the problem requirements, but final evaluation of the applicability and appropriateness of the solution has not been completed, it is called a potential transfer. Twelve potential transfers of technology are in various stages of evaluation as of July 15, 1968. They are discussed in the following paragraphs. The discussion format is similar to that previously used in discussing transfers, with the exception that an additional topic is included which gives an indication of the likelihood that an actual transfer will result.

DU-9

Four-Channel Telemetry System for Experimental Work With Dogs

Dr. A. G. Wallace, Duke University Medical Center

Description and Solution:

Dr. Wallace has need of a four-channel telemetry system of small size. It is to be used as a means of gathering data on physiologic parameters of live experimental animals, primarily dogs. It appears that the requirements of this application can be satisfied by a multichannel telemetry system designed by Ames Research Center. Recent information obtained from Ames indicated that design work on a multichannel telemetry system has been completed. This circuit development work has been in progress by Mr. Tom Fryer at Ames for approximately eight months, and it was anticipated that the results would be applicable to this problem. Technical information has been forwarded to the researcher at Duke University, and it appears that the Ames system will accomplish the required function.

Successful Searching Method:

Tech Brief and personal contact with researchers at Ames Research Center.

Source of Solution:

Ames Research Center

Benefits to be Derived from Transfer:

Procurement of a suitable telemetry system will permit the researcher to gather information on experimental animals which he cannot now obtain.

Current Status:

Presently, the optimum manner for obtaining these units is being sought.

Prognosis for Actual Transfer:

An estimate of the likelihood of actual transfer must await completion of efforts to obtain the telemetry units.

DU-10

Techniques for Monitoring Heart Rate, Rapid Changes in Blood Pressure, and Detecting Arrhythmias Directly and Automatically from Physiological Data

Dr. A. G. Wallace, Duke University Medical Center

Description of Problem and Solution:

This problem represents in reality a number of specific problems related to monitoring patients in cardiac intensive care units. After an initial investigation, it was decided that meaningful solutions would come in the form of sound engineering and that searches for new technologies would not be extremely fruitful. However, as a result of periodically reviewing all problems which are encountered in this program and continually attempting to relate these problems to new technology, it was possible to suggest a unique approach in the area of patient monitoring within the context of this problem.

The problem referred to here relates more to research than to patient monitoring at the present time. Specifically, it is the opinion of medical investigators that changes in electrocardiographic (EKG) signals precede the onset of cardiac failure by a significant period of time. It would be

very valuable to be able to study these EKG signals immediately prior to the onset of cardiac failure. It is not feasible, however, to record these signals on tape continuously for a large number of patients, as would be required for such a study. At present,the approach is to use an endless magnetic tape which monitors one patient and stores past EKG signals for a specific interval of time. When a cardiac failure occurs, the tape transport is stopped, and the EKG preceding the failure is recovered. Equipment to accomplish this, unfortunately, is quite expensive. As a result, a large number of these units is not available, and progress of research is relatively slow. Additionally, the stored information represents only a relatively short period of time preceding the failure.

During a recent visit to the Manned Spacecraft Center, discussions with Dr. Edward Moseley of the Medical Operations Research Branch indicated that EKG signals can be stored in very compact form using what is called a contourograph. The output of this instrument is a series of single EKG complexes recorded on light-sensitive paper. For each complex, time proceeds from left to right horizontally on the record, and successive complexes are displaced vertically downward on the record. This gives, in essence, a two-dimensional image with time increasing at different rates both from left to right and top to bottom. This technique of data compression was discussed with Dr. Wallace at the Duke University Medical Center, and it was learned that he was quite familiar with the technique but had not considered it because it is extremely difficult to obtain quantitative information. If, however, the attempt to establish a digital image processing center in this region is successful, it will be possible to extract quantitative data from contourograms very rapidly and to process and display the results in almost any desirable manner. Thus, this represents a potential improvement in presently used techniques of research involving continuous patient monitoring.

Successful Searching Method:

Personal contact with NASA researcher.

Source of Solution:

Manned Spacecraft Center

Benefits to be Dervied from Transfer:

If this type of information can be obtained on a clinical basis, it will be an extremely valuable aid in cardiac intensive care units.

Current Status:

Implementation of this technique cannot begin until a digital image processing center is available in this geographic area.

Prognosis for Actual Transfer:

The likelihood that this technology can be applied depends on the establishment of a digital image processing center in this region, so that until this occurs the possibility of actual transfer cannot be evaluated.

DU-11

Pressure Transducers for Intracavity or Subcutaneous Implantation in the Body and

DU-31

Catheter-Mounted Pressure Transducers

Dr. M. S. Spach, Duke University Medical Center

Description of Problem and Solution:

The problem of measuring pressure at various points within the circulatory system, as well as other physiological systems, such as in the urinary tract, is a severe one. Most of the determinations in the past have been made by inserting a catheter to the point at which it is desired to determine pressure. Blood then flows out through the catheter and makes contact with an external pressure transducer. Pressure information is transmitted through this column of blood to the transducer which is physically too large for insertion into the body. Much information is lost because of the propagation characteristics through this column of blood.

Recently, smaller pressure transducers have been fabricated which utilize semiconductor strain gauges mounted on a thin membrane. These devices have been made small enough for insertion into the body and have, in fact, been inserted or implanted directly in heart chambers. Such devices are presently available from Electro-Optics, Inc. These devices have resulted from NASA-supported research and development programs. Generally, they are considered to be relatively expensive by the medical profession, and additionally, they involve passing electrical current into the body which is felt to be undesirable. There is always a chance that, if currents are applied to heart tissue, the heart can go into fibrillation which is essentially an unsynchronized and ineffective state of activity of the heart.

An entirely new approach to measuring pressure within the body has been developed by Dr. Max Anliker at Ames Research Center which appears to offer many advantages over previous types of transducers. This particular approach is an optical one and involves the passage of only optical energy into and out of the body. Briefly, it operates by sending light down an annular bundle of optical fibers to a thin diaphragm placed at the end of a catheter which is inserted into the body. The light is reflected from the inner surface of the diaphragm to an inner or outer bundle of optical fibers depending on the differential pressure existing on the two sides of the diaphragm. These optical fibers sense the direction of reflected light from the inner surface of the diaphragm, and pressure information can be obtained from the differential output of the two bundles of optical fibers.

Successful Searching Method:

Personal contact with researchers at the Ames Research Center.

Source of Solution:

Ames Research Center

Benefits to be Derived from Transfer:

Small pressure transducers of this nature which can be inserted into the body in order to make pressure measurements at the point where the

measurement is desired will yield greater information about the pressure distributions present in the body than the conventional methods using catheters and external pressure transducers because of the loss of information caused by the propagation characteristics through this column of blood.

Current Status:

The Research Triangle Institute has received from the Ames Research Center several catheter tips with thin diaphragms which can be used to construct the transducer. In addition, we have obtained from Langley Research Center a new type of low attenuation plastic optical fiber for use in this system. Fabrication of the transducer is now in process.

Prognosis for Actual Transfer:

Actual transfer and a demonstration of the transducer in use must await fabrication of the device. When the devices are available, evaluation of these units will be initiated at Duke University Medical Center and the Medical School at the University of North Carolina.

UNCD-12

Method of Measuring Subglottal Pressure

Dr. D. W. Warren, Dental Research Center, University of North Carolina

Description of Problem and Solution:

This problem involves the measurement of air pressure in the subglottal region in children with varying degrees of cleft palate defects. Dr. Warren is seeking to correlate the degree of speech intelligibility with the amount of palate damage in a clear manner. A significant parameter is the ability of a child to generate a pressure in the subglottal region. Measurement of this parameter, however, is difficult and extremely uncomfortable to the children. In addition, the currently available techniques involve difficult calibration procedures to obtain meaningful air pressure measurements.

The optical pressure transducer developed by Dr. Max Anliker at the Ames Research Center appears to offer promise of performing the measurements required in this application. Mr. George Edwards of the Technology Utilization Office at Ames Research Center has supplied the most important component of the pressure transducer to the RTI Biomedical Applications Team to use in evaluating the transducer as a device for direct measurement of pressure in heart chambers. When fabrication of an experimental unit is completed, it will be tested for this application as well.

Successful Searching Method:

This pressure transducer was identified as a result of activities seeking pressure transducers for other applications.

Source of Solution:

Ames Research Center

Benefits to be Derived from Transfer:

Knowledge of this parameter will permit experiments to be devised to establish the relationship between nasal resistance and speech intelligibility.

Current Status:

We are awaiting fabrication of one of the optical transducer devices so that a demonstration may be given to the researcher.

Prognosis for Actual Transfer:

Evaluation of the likelihood of an actual transfer occurring in this case must await demonstration of the equipment to the researcher.

UNCD-27

A Method of Maintaining a Thin Tissue Section in Exact Position With Respect to an X-Ray Film for an Indefinite Period

Dr. W. J. Waddell, Dental Research Center, University of North Carolina

Description of Problem and Solution:

Dr. Waddell is studying the distribution of compounds in whole mice using a radioactive isotope technique. The mouse, after injection of the

compound, is quick frozen. Then, the whole mouse is sectioned using a microtome. The resulting section, with the radioactive tracer present, is superimposed on an X-ray film which is then exposed and developed. The section is maintained in contact with the film throughout the exposure, development, drying, and the remaining period of usefulness of the slide. Using an optical microscope, the image on the film is compared with the section which lies over it to obtain correspondence between the location of radioactive compound indicated in the film emulsion exposure and the physical location with respect to the mouse section which overlies it.

The maintenance of absolute registry between the slide emulsion and the mouse section during the entire process has proved to be a difficult problem. An approach which will provide permanent bonding between the mouse section and the film emulsion and which will, at the same time, permit development of the film using ordinary development techniques is needed. The potential solution being considered for application to this problem involves the use of X-ray film stripping techniques and a special dry contact cement.

Successful Searching Method:

Information on Kodak stripping films and special adhesives has been obtained as a result of telephone contacts with the Special Sensitized Products Sales Division of Eastman Kodak Company.

Source of Solution:

The basic idea for the use of stripping type X-ray films in this application was furnished by a member of the Biomedical Applications Team. Information on the availability of stripping type X-ray films was obtained from the Eastman Kodak Company.

Benefits to be Derived from Transfer:

Successful solution to this problem will permit the distribution of compounds in these research animals to be determined more accurately than can be done using present methods. This type of study is important because of the desirability of obtaining information on the parts of these

animals in which certain compounds are concentrated. For example, it is useful to know whether certain compounds cross through the placental membrane and actually accumulate in embryos or whether the embryo is unaffected by the compound. This type of procedure and analysis finds utilization in a number of other areas as well.

Current Status:

Further information is being gathered on dry adhesives which can be used to provide the bond between the stripping film and the mouse section.

Prognosis for Actual Transfer:

The success of the proposed method revolves essentially around solution of the adhesive problem. The adhesive must be dry; i.e., it must contain no or very little solvent, and the bonding film must be very thin, less than 1 micron. Several adhesives must be evaluated to determine their actual applicability to this problem.

WF-3

Prosthetic Valve for Urinary Tract

Dr. W. G. Montgomery, Bowman Gray School of Medicine
Wake Forest University

Description of Problem and Solution:

The researchers working on this problem are seeking a prosthetic valve suitable for implantation in the urinary tract. A number of configurations have been studied, but no device that is satisfactory from all standpoints has been found. The problem is complex in that it involves a number of different aspects. First, regardless of how one might go about designing a valve and a remote actuating device, there is a material problem in fabricating such a device. Specifically, incrustation occurs on most materials which can be used for valve construction. This is, of course, undesirable since the incrustation build-up can lead to failure of the device. If the valve were to be constructed of a material on which incrustation occurred, then some means of cleaning the valve in situ would be

required. Silastic has proved to be the best material available, from an incrustation standpoint. The operating life of the valve must be at least four years, since the operation required to implant the valve is a major one and cannot be performed frequently.

Aside from the incrustation problem, there are also the dual problems of small size and remote actuation of such a valve. The valve must be constructed in such a fashion that it can be actuated from outside the body without invasive techniques, such as wires, etc. A number of publications have been furnished to the researchers, but two NASA publications, SP-5019 Advanced Valve Technology and SP-5905 Seals and Sealing Techniques, were considered to be very relevant to their problem.

In addition to these informational activities, detailed consultations have been held by members of the Biomedical Applications Team with the researchers concerning the specific problems of design and fabrication involved in constructing a suitable valve for implantation in dogs. Resulting from these discussions, a design for experimental implantation in dogs is being evolved. The final design of such a valve is now in process of specification, and the Research Triangle Institute is preparing to fabricate one of the units for the researchers.

Successful Searching Method:

Specialized NASA publications on valve technology and sealing techniques plus experience of Biomedical Applications Team members and researchers.

Source of Solution: Joint consultation between researchers and Biomedical Applications Team member.

Benefits to be Derived from Transfer:

It is difficult to overestimate the importance of finding a solution which can be applied to man since the most common cause of death in paraplegics is urinary infections. Development of a device suitable for implantation in dogs is an important first step in solution of this problem.

Current Status:

Design of the device for implantation in dogs is being finalized, preparatory to fabrication of an experimental unit by the Research Triangle Institute.

Prognosis for Actual Transfer:

Present considerations indicate that a satisfactory device for implantation in dogs will be accomplished in several months.

WF-29

An Electrode for Measuring Hydrogen Ion Concentration and Carbon Dioxide Partial Pressure in the Blood

Dr. C. E. Rapela, Bowman Gray School of Medicine
Wake Forest University

Description of Problem and Solution:

An electrode for measuring hydrogen ion concentration and carbon dioxide partial pressure in the blood is needed. The response time of the electrode should be 30 seconds or less. Currently available devices have a response time which varies from 90 seconds to 2 minutes.

Investigators at the Bowman Gray School of Medicine, Wake Forest University are interested in making continuous measurements of the carbon dioxide content of blood outflowing from the brain or in the brain tissue. The response of certain areas of the brain to stimuli are considered to be related to the carbon dioxide partial pressure in the blood. These carbon dioxide pressure variations in the blood are thought to occur in less than 30 seconds while the response time of the commercially available electrodes is of the order of two minutes. The potential solution which has been identified is a rapid response method of measuring CO_2 in blood developed by researchers at the Brooks Air Force Base, USAF Aerospace School of Medicine.

Successful Searching Method:

Computer search of aerospace literature.

Source of Solution:

Brooks Air Force Base, USAF Aerospace School of Medicine

Benefits to be Derived from Transfer:

A means of obtaining rapid carbon dioxide pressure measurements in the blood in the brain will permit observation of the CO_2 response of certain areas of the brain to stimuli which has not been previously obtained.

Current Status:

The researcher is evaluating the method which has been identified.

Prognosis for Actual Transfer:

An estimate of the probability that the identified technology will be useful to the researcher must await evaluation of the proposed method by the researcher.

WF-33

Application of Biotelemetry Units to Intensive Care Areas

Dr. R. A. Kemp, Bowman Gray School of Medicine,
Wake Forest University

Description of Problem and Solution:

Members of the Department of Surgery of the Bowman Gray School of Medicine are interested in improving the quality of their patient monitoring in the intensive care unit. The present intensive care unit has approximately 15 beds located peripherally around a central nurse station. Two hard-wire systems for monitoring EKG from two of the beds at the central nurse station is in use. Present equipment is extremely bulky, both in the patient's room and at the nursing station, and requires physical attachment of wires to the patient. This clutter of equipment around the bed is extremely inconvenient, and the researchers are very interested in some means of reducing equipment size and complexity while, at the same time, improving the monitoring facilities. Specifically, they would like

to monitor EKG and respiration rate from each bed at the central nursing station. It is very desirable that wires not be attached to the patient; therefore, a telemetry unit is necessary. A conventional electrode system can be used for the EKG; however, an investigation of the different approaches to monitoring respiration will be necessary to determine the optimum technique.

Search No. 697 on Biotelemetry which has been updated through December 1967 has been supplied to the researchers for their evaluation. In addition, information on the Ames Research Center miniature biopotential telemetry system was furnished in the form of the supplemental information brochure compiled by Ames. Evaluation of the Ames telemetry unit was very favorable, and it appears that the basic design would perform the telemetry function required. It is realized that there are a number of commercial monitoring systems which are presently available on the market. In this case, less complex monitoring (and, consequently, less complex equipment) is required than that provided by currently available commercial monitoring systems. Indeed, the basic reason for promulgation of this problem is the emphasis on providing a simple system for basic monitoring that does not involve bulky equipment or instrumentation on the individual or in the room.

Successful Searching Method:

The Ames Biotelemetry System was identified on an earlier problem by means of NASA Tech Briefs and personal visits to the Ames Research Center.

Source of Solution:

Ames Research Center

Benefits to be Derived from Transfer:

Successful implementation of a biotelemetry system for use in intensive care wards would greatly alleviate the crowded condition and the equipment clutter that currently exists around the bed of patients in such wards.

Current Status:

The Research Triangle Institute is preparing a cost estimate for the researcher.

Prognosis for Actual Transfer:

It seems clear that the Ames biotelemetry systems could be applied successfully to the subject problem. The matter of cost and funding, however, must be resolved before actual transfer can take place.

WF-36

Implantable Pressure Sensor and Telemetry Unit for Measurement of Fluid Pressure in the Cranial Cavity

Dr. D. L. Kelly, Jr., Bowman Gray School of Medicine
Wake Forest University

Description of Problem and Solution:

A researcher in the Department of Neurosurgery at Bowman Gray is engaged in research activities associated with the build-up of fluid pressure in the cranial cavity. Many people have a fluid build-up that occurs in the cranial cavity, and this pressure must be relieved. This is usually accomplished by inserting a pickup tube inside the cranial cavity and running a piece of tubing down underneath the skin in the rear of the head, finally discharging the fluid into one of the blood vessels where the fluid is dispersed. A special one-way valve known as a Holter valve is used to prevent passage of blood into the cranial cavity. Not infrequently, this valve will stick closed, and pressure will begin to build up in the cranial cavity of the individual. Monitoring of the pressure in the cranial cavity must be accomplished by means of a small pressure transducer and then telemetered outside the body for pick up. The Ames Research Center implantable pressure biotelemetry system seems feasible for this application, if the operating life of the transmitters can be extended sufficiently.

Successful Searching Method:

Information on the Ames pressure biotelemetry system was already available to the Biomedical Application Team at the time this problem was proposed. The information on the Ames biotelemetry system orginally resulted from NASA Tech Briefs on the subject and visits to the Ames Research Center.

Source of Solution:

Ames Research Center

Benefits to be Derived from Transfer:

The required instrumentation and telemetry system would permit the gathering of data which is not now available on pressure buildup in the cranial cavity.

Current Status:

The Research Triangle Institute is currently preparing a cost estimate on fabrication of a biotelemetry system modeled after the Ames units using discrete components. This information will be used by the researcher to establish feasibility for his particular application. In addition, specifications and information on long-term telemetry are also being gathered for his evaluation.

Prognosis for Actual Transfer:

Incomplete.

WF-52

Methods of Triggering From a Fixed Reference Point on the EKG Waveform

Dr. G. L. Malindzak, Jr., Bowman Gray School of Medicine, Wake Forest University

Description of Problem and Solution:

Dr. Malindzak at Bowman Gray School of Medicine, as a part of his research, is accumulating large amounts of data on the cardiovascular system. These data all bear a fixed relationship to the heart cycle. In order to simplify the data processing and recording aspects of his research, it is desirable to obtain a fixed reference point in each cardiac cycle which can be used as a trigger. The potential solution involves a cardiac R-wave detector developed at the Lewis Research Center.

Successful Searching Method:

The cardiac R-wave detector was originally brought to the attention of the Biomedical Applications Team by a Tech Brief. Follow-up with the

TU officer at Lewis Research Center provided the detailed information on circuitry required for implementation.

Source of Solution:

The detailed report which gives sufficient information to construct a cardiac R-wave detector was contained in NASA publication TM X-1489.

Benefits to be Derived from Transfer:

Implementation of this circuitry will permit the accumulation of cardiovascular data in a much more useable form.

Current Status:

Information on the cardiac R-wave detector has been given to the researcher for his evaluation.

Prognosis for Actual Transfer:

It appears extremely likely that this circuitry, or portions thereof, will be useable to the researcher in his program.

WF-55

A Simple Means of Sensing Whether a Respirator is Actually Performing the Respiratory Function on Humans

Dr. R. A. Kemp, Bowman Gray School of Medicine, Wake Forest University

Description of Problem and Solution:

Dr. Kemp is interested in a very simple and reliable means of sensing whether a respirator is actually performing the respiratory function on the patient or whether, through some malfunction, the patient is not actually being respired by the respirator. The type of respirators in use by the researcher is designed so that it pumps into the respiratory passages of the patient until a fixed pressure is obtained. When the fixed pressure is reached, the ventilation phase is ended, and the expiration phase of the cycle begins. If, because of some obstruction or because of a kink in the respirator hose, the patient is cut off from the respirator, the machine is unable to sense this condition. It merely pumps up against

the pressure in the hose until the desired pressure is reached and then cuts off and begins the remaining part of the cycle. As a result, it is possible for the respirator to be operating perfectly, from a mechanical standpoint, and the patient can be deprived entirely of his air supply and thus die. Nose clip type sensors have been employed, but they are not very satisfactory because they are very difficult to maintain in place and are bulky. In addition, quite frequently the airway resistance through the nasal passages is such that it is desirable for the respirator input to be shunted so as to enter through the throat. The potential solution involves the use of a thermistor detector placed in the respirator tubing, with the temperature of the incoming and outgoing air being monitored by an external monitor. The temperature pattern of a patient that is being properly ventilated, as opposed to the respirator pumping against an obstruction, is felt to be sufficiently different so that a discrimination between these two conditions can be obtained by analyzing the time rate of change of temperature in the respirator tubing.

Successful Searching Method:

Experience of Biomedical Applications Team member.

Source of Solution:

Biomedical Applications Team Member

Benefits to be Derived from Transfer:

A simple, reliable, easily instrumented detector which could determine whether a respirator is actually performing its function on a patient would be an extremely useful device in intensive care units. Such a device can be used to trigger an alarm upon malfunction of the regulator so that immediate action can be taken by medical personnel in the intensive care unit without the requirement for constant surveillance.

Current Status:

The Research Triangle Institute is currently preparing a cost estimate on the construction of such a unit for the researcher.

Prognosis for Actual Transfer:

Final evaluation must await fabrication of an experimental unit.

4.0 Active Problems

In addition to those problems which have already been discussed as transfers or potential transfers, there are a number of problems which have been identified by the Research Triangle Institute's Biomedical Applications Team that are considered to be active problems. By the term active, we mean that the problem is still under consideration, and solutions are being sought on some regular review basis or on a continuing investigative basis; i.e., the problems are considered to have a sufficiently high probability of solution as to warrant further activities. The active problems effective July 15, 1968 are:

Duke University Medical Center, Durham, North Carolina

- DU-7 Microforce Transducer.
- DU-8 Methods of Studying Quantitatively Diseased Membranes in Different Joints of the Body.
- DU-16 Visual Discrimination in Photos and X-ray Pictures.
- DU-20 Multielectrode Needles.
- DU-21 Method of Measuring Radial Component of Ionic Current Flow Through Nerve Membrane.
- DU-24 Instrumentation for Obtaining EKG of Developing Chick Embryo Heart.
- DU-30 Technique for Heparinizing Catheters.
- DU-32 Resolution Improvements in Ultrasonic Holography by Analytical Methods.
- DU-33 Fabrication Source for Special Purpose Catheter to be Used in Left-Heart Bypass.
- DU-34 Electronic Control and Synchronization System for Left-Heart Bypass Pump.
- DU-35 Information on the Use of Digital Image Processing for Plotting Trajectories of Positions on Heart Wall Throughout Cardiac Cycle.

University of North Carolina Medical School, Chapel Hill, North Carolina

- UNC-7 Determination of Radiation Dose as a Function of Position of Radioactive Needles or Wires in the Body.
- UNC-10 A Portable EKG Tape Recorder.
- UNC-11 A Semi-Portable Instrument for Measuring Blood Pressure.

UNC-15 Quick and Accurate Measurement of the Angle Which Each Finger Segment Makes with Adjacent Segments.

UNC-16 Identification and Quantification of All the Amino Acids in Urine Quickly.

UNC-17 Materials for Microtome Knives Other Than Steel and Glass.

UNC-18 Means whereby a Few mm^3 Tissue Specimen can be Cooled from Body Temperatures to -80°C in a Few Milliseconds.

UNC-21 Simple Techniques for Telemetering Blood Pressures.

UNC-22 Means to Quickly Identify What a Drug-intoxicated Person Has Ingested as soon as He is Admitted to the Emergency Ward.

UNC-23 Implantable Plastic Materials.

UNC-25 Methods for Detecting (Screening) Skeletal or Striated Muscle Relaxants.

UNC-26 Better Assay Methods, than Bioassay, for Succinyl Dicholine at the Microgram Per Milliliter Level in Serum.

UNC-27 Methods for Assay of Succinyl Monocholine in Serum.

UNC-28 Techniques for Measuring Free Fatty Acids in Serum.

UNC-29 Techniques for Maintaining Blood Sugar at a Constant Level over a Period of Several Hours.

UNC-30 Parameters Other than Blood Sugar and Fatty Acid Levels which Can Be Used to Follow Utilization of Insulin.

UNC-31 Techniques Available for Measuring Metabolic Products of Anesthetics in Breath and Body Fluids.

UNC-32 Methods for Measuring, Externally, the Extent of Atherosclerosis in a Limb Artery or Aorta.

UNC-33 Techniques for Recording or Telemetering Heart Rate, Blood Pressure and Respiration of Swimming and Diving Animals.

UNC-34 A Device for Warming Blood.

UNC-35 A New Device for Measuring Carbon Dioxide in Expired Gases.

UNC-36 A Device to Measure Breath Volume of Patients on Operating Tables.

UNC-37 Prevention of Orthostatic Hypotension.

UNC-38 Electromyography as an Aid to Hand Rehabilitation.

UNC-39 Recording and Quantification of Electromyographic Signals.

UNC-40 Instrumentation for Infant Behavior.

UNC-41 Material for and Fabrication of Vasectomy Clip.

UNC-42 A Means to Collect Exhaled Breath.

UNC-43 Instrumentation for Automatic Read-out of Tissue Temperature as a Function of Time and Distance from a Probe Maintained at -40°C.

University of North Carolina Dental School and
Dental Research Center, Chapel Hill, North Carolina

UNCD-1 A Method of Producing Silver-Copper and Silver-Tin Alloys in Powder Form with Spherical Shape and with Particle Sizes in the Range of 2 to 4 and 6 to 10 microns.

UNCD-3 A Means to Obtain Rapidly a Pictorial Representation of the Temperature Distribution of the Interior of the Oral Cavity in Humans.

UNCD-5 An Improved and Reliable Electrical Tooth Pulp Tester.

UNCD-6 A Small Sensor to Measure Viability of Human Teeth.

UNCD-15 A Device to Measure Looseness of Teeth.

UNCD-16 A Sensor to Measure Stress Distribution in Bone as a Result of Applied Force.

UNCD-17 A Method of Measuring Tongue-Lip Pressures on the Teeth.

UNCD-18 Method of Determining if Tooth Roots are Attached to the Jaw Bone Structure.

UNCD-19 A Means of Applying an Electric Field to the Root of the Tooth in Order to Stimulate Bone Resorption.

UNCD-20 A Means of Applying Force to Teeth so that Orthodontic Correction in the Position of the Teeth can be Achieved.

UNCD-21 A Method of Measuring the Relative Displacement of Teeth with Respect to Some Fixed Point.

UNCD-22 A Method of Measuring the Force Applied to a Tooth by an Orthodontic Structure.

UNCD-23 An Improved Metal with Low Corrosion Rate and High Elastic Modulus for Orthodontic Fixtures.

UNCD-24 Adhesive to Glue Brackets to Teeth.

UNCD-25 A Miniaturized Electrical System to Shock the Tongue of Patients when it is Pressed Against the Rear of Their Teeth.

UNCD-26 A Method of Measuring the Height of Bone with Respect to the Teeth in the Jawbone Structure.

North Carolina State University, Raleigh, North Carolina

NCSU-1 The Application of Mathematical Modeling Techniques to the Cardiovascular System.

Wake Forest University, Bowman Gray School of Medicine,
Winston Salem, North Carolina

WF-20 A Technique for Continuously Monitoring the Inside and Outside Diameter of Capillaries and Small Arteries and Veins.

WF-21 A Method of Measuring Velocities of Individual Red Cells.

WF-23 An Effective Respirator for Infants.

WF-24 Respirator Control System that Adjusts Both Volume and Rate as Well as other Parameters According to Body Needs Determined by Monitoring Continuously the Partial Pressures of Gases in the Blood Stream.

WF-27 An Electrode or Other Type System with Rapid Response to Measure CO_2 Content of Blood in the Brain.

WF-28 A Method of Mixing Indicator with Blood as it is Injected into Veins and Arteries and a Method of Mixing again just before the Sampling Site.

WF-31 A Servo-Controlled System to Measure pO_2 and pCO_2 in Expired Gases and to Control the Operation of Respirators.

WF-32 Oxygen Toxicity Effects.

SF-35 Oxygen Tension in Tissue.

WF-37 An Implantable Valve which can be Remotely Opened and Closed from Outside the Body.

WF-38 An Inexpensive Sterile Fabric for Sheets, Operating Room Gowns, Tissue Transfer, Etc.

WF-40 Localization of Blood Pools in Various Cavities of the Body.

WF-41 Low Cost, Swallowable, Temperature Sensing Telemetry Capsule.

WF-42 Ventilators for Small Animals.

WF-43 Means of Defining Driver Tasks for Automotive Drivers.

WF-44 A Means of Reducing Dose Rate While Taking X-ray Cine-Radiographs.

WF-46 An Artificial Hand with Touch and Prehension Pressure Feedback to the Human Operator.

WF-47 Information on Techniques and Advances in Thermography.

WF-48 Information on Cardiovascular Systems.

WF-49 Information on Sensors, Transducers, and Electronic Circuitry Adaptable to Medical Applications.

WF-51 The Effect of Trace Amounts of Specific Metals on Metabolism.

WF-53 Means of Obtaining the Velocity Spectrum of Blood Flowing in Arteries and Veins.

WF-54 An Improved Sensing System for Indicator Dilution Studies.

In addition to the three previously mentioned universities where our major activities are concentrated, we also have auxiliary activities with a number of other agencies and are carrying active problems from them. These agencies and the problems associated with each are listed below:

Hospital for Special Surgery, New York, New York

HSS-2 A Method for Measuring and Telemetering Pressures on the Surface of Prosthetic Hip Joints.

Veterans Administration Hospital, Durham, North Carolina

VA-1 Improved Techniques for Measuring Blood Flow Continuously.

VA-3 Transducers which can Measure Blood Pressure and are External to the Body.

New York University, New York, New York

NYU-1 Diagnostic Test for Glaucoma.

These problems are discussed in the Quarterly Reports No. 1[1], No. 2[2], and No. 3[3] which were written in partial compliance to the reporting requirements under this contract.

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[1] "Biomedical Applications Team," Contract No. NSR-34-004-045, Quarterly Progress Report 1, 15 June 1967 to 14 September 1967.

[2] "Biomedical Applications Team," Contract No. NSR-34-004-045, Quarterly Progress Report 2, 15 September 1967 to 14 December 1967.

[3] "Biomedical Applications Team," Contract No. NSR-34-004-045, Quarterly Progress Report 3, 15 December 1967 to 14 March 1968.

5.0 Information Searching

5.1 Computer Searches

During this contract period a total of 19 new information searches were made of the NASA Aerospace Literature. The searches were performed for the Biomedical Applications Team under contract by the North Carolina Science and Technology Research Center in the Research Triangle Park, North Carolina. Information obtained from these searches has been used to support the searching activities associated with the medical problems which have been active during the contract period. In many cases, the searches were of sufficient utility so that they could be applied to several different specific problems. In addition, it has not been uncommon for similar types of problems to be identified at the different institutions which the Biomedical Applications Team service. As a result of this, the total figure of 19 information searches does not fully convey the utility of the information obtained as a result of these computer searches. Indeed, the information resulting from these computer searches has been applied during the contract period to some 40 to 60 per cent of the total active problems. Information searches made during this contract period are listed below:

Subject	Search No.
List of Technical Surveys	965
Effects of Weightlessness on Skeletal Calcium	980
Blood Coagulation	1008
Assay of Microorganisms	1060
Measurement of Oxygen and Carbon Dioxide in Blood and in Expired Air	1094
Surveys and Program Reports (Part I & II)	1115
Blood Flow Meters	1128
Autoradiography	1130
Oxygen Tension in Tissue	1135
Hemodynamic Models	1151
Liquid Flow Measurement	1162
Closed Fluid Systems	1208

Personal Communications Equipment	1210
Short Half-Life Radiation Medicine	1212
Task Definition	1246
Chromium and Metabolism plus Trace Elements and Metabolism	1277
Oxygen Toxicity	1294
Glaucoma and Nonconventional Pressure Measurements	1301
Ultrasonic Transducers	1328

In addition to the basic information searches that were performed, a number of searches, not only new searches but also searches made under the previous contract,were updated during this contract period. A total of 10 searches were updated. They are:

Subject	Search No.
Biotelemetry	679
Electromyography	680
Prosthetics	768
Physical Criteria for Astronaut Selection	775
Biomedical Pressure Sensors	905
Computer Processing of Physiological Data	924
List of Technical Surveys	965
Effects of Weightlessness on Skeletal Calcium	980
Surveys and Program Reports	1115

In addition to formalized computer searching of the aerospace literature, we have extensively used another searching method to obtain information from the NASA information banks. Namely, we have on numerous occasions requested a manual search on very specific topics in the aerospace literature. These manual searches are performed in somewhat the following manner. If the subject of the problem is considered to be extremely specific, then the NASA index and thesaurus are consulted using specific indexing terms to determine the number of documents in that subject area that are available in the NASA information system. If the number of documents is small; i.e., generally in the order of

10 or less, then it is more feasible to merely pull all the documents under that index term and evaluate either them or their abstracts without resorting to a computer search. This is not only less expensive, but it is also much quicker. This procedure has been an extremely effective and a very useful adjunct to our normal computer searching procedures. These types of manual searches have been undertaken on some 30 per cent of the active problems during this contract period.

5.2 Problem Abstracts

Another formal information searching method employed by the Biomedical Applications Team is the Problem Abstract. The Problem Abstract defines in a clear and concise manner the problem to which the medical researcher seeks a solution. These problem abstracts are disseminated to the NASA research centers where the technology utilization officers place the Problem Abstracts in the hands of personnel whom he feels are likely to be in a position to provide responses to the problem as a result of their experience or research interest. During the contract period, seven formal Problem Abstracts have been prepared. These Problem Abstracts are:

UNCD-3	-	A Means to Obtain Rapidly a Pictorial Representation of the Temperature Distribution of the Interior of the Oral Cavity in Humans.
UNCD-6	-	A Small Sensor to Measure Accurately the Surface Temperature of Human Teeth.
UNCD-11	-	An Improved Bacteria Sampling Technique.
UNCD-12	-	A Method of Measuring Subglottal Pressure.
WF-28	-	Blood Flow Volume and Blood Flow Rate in Vascular Systems Using Indicator Concentration Methods.
WF-29	-	An Electrode for Measuring Hydrogen Ion Concentration and Carbon Dioxide Partial Pressure in the Blood.
WF-30	-	An Improved Blood Vessel Constrictor.

As a result of the dissemination of Problem Abstracts and formal quarterly reports generated by the Biomedical Applications Team during this and the previous contract period, a total of eight responses have been received from

various individuals at the NASA research centers. Three responses were received on Biomedical Problem UNC-1. One response each was received on Biomedical Problems UNC-5, UNC-35, UNCD-1, UNCD-6, and WF-3.

5.3 Other Searching Methods

In addition to these more or less formalized methods for obtaining information which relates to the solution of biomedical problems, the Biomedical Applications Team has utilized three other information sources in seeking answers to biomedical problems. First, in every case the combined experience of the Biomedical Applications Team members has been applied to the problems to ascertain if there exists within their knowledge and experience practical solutions to each problem. Indeed, this particular method of searching using the experience of technically trained personnel has not been limited only to members of the Biomedical Applications Team. In fact, many specialists in the various disciplines of engineering and research have been routinely consulted to obtain information and advice on specific problems as deemed appropriate.

Another source of information relating to Biomedical Problems is the open literature. The Biomedical Applications Team scans many of the related technical journals and biomedical engineering journals on a routine basis in order to maintain an awareness of techniques and equipment which are being developed. Access to the medical literature is maintained by use of Index Medicus which is available to all members of the Biomedical Applications Team.

Finally, in all biomedical problems which involve measurement, instrumentation, or hardware, the commercial literature is surveyed to insure that items have not already been developed which will fulfill the researcher's need. If commercial items are identified which can fulfill the researcher's need, he is, of course, apprised of the availability of such equipment. Keeping abreast of the product output of all the manufacturers of biomedical instrumentation is, however, a formidable task. To permit a reasonable degree of thoroughness in surveying the available instrumentation and hardware for use in the biomedical field, a file of available equipment from biomedical manufacturers is maintained by the Biomedical Applications Team. To aid in

this process of keeping abreast of commercial suppliers, the services of STRC are used to search the Sweet's Industrial Information System which is an indexed, rapid-access, microfilmed catalog of the products of 5,670 equipment suppliers in the United States.

6.0 Problem Review

During the year a periodic review, on a quarterly basis, has been conducted of all the problems which have been documented by the Biomedical Applications Team. In each case, the purpose of this review was to eliminate from the active problems those problems which are no longer considered to be active. There are various reasons for which problems are classified as being inactive. These reasons are:

(a) Successful transfer.

(b) Satistfactory solution has been identified but transfer cannot be completed for economy or other reasons.

(c) Researcher has no further interest in the problem.

(d) Problem as originally stated was too broad or general.

(e) Researcher has found his own solution.

(f) Problem is too difficult; i.e., the problem as given to the Biomedical Applications Team is presently the focus of large expenditures of money, research, and developmental effort so that the liklihood of success by the Biomedical Applications Team is considered to be sufficiently low as to assign an extremely small probability to solution of the problem.

(g) As a result of personnel transfer in the medical institutions, the problem has either been closed or transferred to another institution along with the investigator and a given new number.

The problems that were closed are listed below. Following each problem title a lettered designation corresponding to one of those in the above list is given.

AEI-1 Multiple Electrode Implant for Communicating with Brains (e)

AEI-2 A Cathode Ray Tube Camera for Ultrasonic Scanning Systems (c)

DU-2 Optical Scanning Concept (c)

DU-3 New Technique for Constructing Safe and Efficient Hemodializers (f)

DU-4 Measurement of Small Temperature Changes (f)

DU-5 EMG Electrode Assembly for the Soft Palate (a)

DU-6 Correction for Latency in Vidicons (a)

DU-12 Techniques for Enhancing Cineradiographs of Kidneys so that the Arterial Network within the Kidney Can Be Mapped (c)

DU-13 Source of K-42 Having Very High Specific Activity (c)

DU-14 Spray-on Electrode (c)

DU-15	Techniques for Analyzing Carotid Artery Pressure Pulse to Obtain Blood Flow Data (d)
DU-17	Storage and Retrieval of Biomedical Texts (d)
DU-18	Special-Purpose, Real-Time Data Processing (e)
DU-19	Low-Cost, Microminiaturized, Reliable Time-Multiplexing and Analog-to-Digital Electronic Equipment (e)
DU-22	Method of Alternately Exposing Tissue to Separate Monochromatic Light Beams Having Different Wavelengths at a Rate of 5,000 Cycles Per Second (f)
DU-25	A Signal-Conditioning and Multiplexing System for Multiple Electrode EKG Patient Monitoring (a)
DU-28	Fluid Dynamics of Sucrose Gap Chambers (a)
MFH-1	Special Materials to be Used in New Hospital Construction (d)
MFH-2	Catheter-mounted Flow and Pressure Transducers (d)
RU-1	A Survey of Computer Techniques for Analyzing Physiological Data (d)
RU-2	A Survey of Recently Developed Transducers for Monitoring Physiological Parameters (d)
UNC-1	Oxygen Measurements in Gas Mixtures (f)
UNC-5	Inserting Needles into Veins (f)
UNC-6	Implantable Plastic Materials (d)
UNC-9	Analyses of Electrophoretic Scan Data (a)
UNC-13	Methods of Reinforcing Thermoplastic Braces and Casts (a)
UNCD-2	Method of Measuring Change and Width of Mandible when Closed and Opened (d)
UNCD-4	Technique for Determining Mechanical Stability of Teeth (d)
UNCD-7	Method of Obtaining X-ray Films of the Entire Mouth on a Single Film with a Depth of Focus of 1 mm or Less (f)
UNCD-8	A Reliable Automatic Processor for Dental X-ray Film (c)
UNCD-9	System for Automatic Scanning and Statistical Analyses of Electron and Photomicrographs (f)
UNCD-10	Techniques for Applying Thermography to the Mouth (d)
UNCD-13	An Economical Dry Heat Sterilization Apparatus (a)
UNCD-14	Design of Clean Rooms, Especially Laminar Flow Rooms (a)
VA-2	Implantable Catheters with Outside Diameter Approximately 0.01 inch (f)
WF-1	Audio Noise Generator (c)

WF-2	Ultrasonic Transducer Positioner (e)
WF-4	Small Aperture Ultrasonic Transducers Having Large Capture Angle (g)
WF-5	Method of Photographing Ultrasonic Energy Patterns (g)
WF-7	Method of Correcting Spherical Aberration in Ultrasonic Holograms (a)
WF-8	Techniques for Analyzing and Obtaining All Significant Information Contained in Ultrasonic Echo Pulses (g)
WF-9	Materials for Prosthetics (d)
WF-10	Theoretical Treatments of Holography which Discuss Aberrations and Distortions (a)
WF-11	Mechanical Joints, Extensions, etc. That Can be Used in Powered Prosthetics (d)
WF-12	Variable Diameter Probe for Electromagnetic Blood Flow Meter (g)
WF-14	Spin Resonance Studies of Physiological Tissue Which Has Been Exposed to Radiation (g)
WF-15	Information on Damage to Physiological Tissue Exposed to Low Levels of Radiation (d)
WF-16	Low Noise Coaxial Cable for Use in Recording Electroencephalograms (c)
WF-17	Helmet Containing Electroencephalograph Electrodes (c)
WF-18	Techniques for Averaging Evoked Nerve Responses That Are Simpler and Less Expensive Than Commercially Available Instruments (d)
WF-19	A Method for Stimulating Nerve Tissue from Outside the Body (b)
WF-22	Improved Methods for Presenting and Enhancing Autoradiographic Scan Data (d)
WF-25	Data Obtained in Ultrasonic Studies of Materials which May Be Relevant to the Understanding of Scattering of Ultrasonic Energy in Physiological Tissue (g)
WF-26	Power Sources for Operating Prosthetic Appliances (d)
WF-34	Fractionation of Gamma Globulin G (f)